Announcements

- Read Messerschmitt Ch 7 for Tuesday.
- Presenters for Thursday
  - Zhuo H Yang (news)
  - Christy Kitmum Loke (news)

Database Tutorial Sessions
Student Talks

- Devin Blann (news)
- George Numair (news)
Client-Server Architecture
(continued)
3-Tier Client Server Architecture example

Client

Application Server

Clicks, keystrokes

What is Bob’s balance?

$0.50

What is Bob’s balance?

$0.50

Shared data
3-Tier Client Server Architecture example

Client

Application Server

- Web Server
- Common Gateway Interchange
- Application Logic

Shared data
3-Tier Client Server Architecture example

- Client
- Application Server
  - Web Server
  - Application Logic
  - Database Management System (DBMS)
  - Database
- What is Bob’s Balance?
3-Tier Client Server Architecture example

In some implementations, Application Logic and Web Server can be put on different machines.
# Relational Database

<table>
<thead>
<tr>
<th>Customer</th>
<th>Balance</th>
<th>Customer Class</th>
</tr>
</thead>
<tbody>
<tr>
<td>Alice</td>
<td>$527</td>
<td>Silver</td>
</tr>
<tr>
<td>Bob</td>
<td>$0.50</td>
<td>Bronze</td>
</tr>
<tr>
<td>Charles</td>
<td>$1000000</td>
<td>Gold</td>
</tr>
</tbody>
</table>
DBMS Responsibilities

- Hide Changes in the Database hardware from the Application

- Standard operations on the data, including searches, such a search is called a query.

- Separate Database Management from Applications, so that many applications can access the same data.

- Security, Integrity, Backup, fault tolerance, etc..
**3-Tier Client Server Architecture in General**

- **Client**
  - Accept instructions from user
  - Make requests of server
  - Display responses of server

- **Application Server**
  - Takes inputs from client
  - Decides what to be done next
  - Decides what shared data to access and manipulates it
  - Processes shared data

- **Shared Data**
  - Support multiple applications with common data
  - Protect critical data
  - Decouple data administration and application administration
Slide adapted from slides for *Understanding Networked Applications*  
By David G Messerschmitt. Copyright 2000. See copyright notice
Sun Case
(continued)
What problems did the micro era produce?

- Desktops are expensive to maintain
  - TCO for windows PC $9900!

- Every PC had a lot of software that had to be maintained
  - Office, Windows, etc...

- Small differences, like the order in which software is installed, could make different PCs behave differently!
Sun’s Vision

- Thin Client model.
- Application Servers with Applications written in Java.
- NCs could retrieve applications from application server as needed.
- Applications compatible with any NC hardware and OS.
- Applications could be fixed, added, updated at the server level, rather than maintaining each PC.
Microsoft Vision

- Keep “fat-client” model
- Add some features to Windows to reduce administration costs
JDBC: Stands for Java Database Connectivity. It is a programming interface that lets Java applications access a database via the SQL language.

RMI: Stands for Remote Method Invocation. It is the method by which a remote Java object from one location can be invoked from other Java virtual machines.

HTTP: Stands for HyperText Transport Protocol. It is the communications protocol used to connect to servers on the World Wide Web.
Sun N-Tier

**Step 1:** The user logs into his client and calls down an application. This message is sent to the Application Server.

**Step 2:** An initial applet is sent to the client. At the same time a servlet is sent to the Webtop Server.

**Step 3:** The applet talks back and forth with the Webtop Server via the LAN.

**Step 4:** As new data is received (i.e., a new customer’s name) the App Server communicates with the database to update that information.

**Remote:** The database and App Server communicate with the Webtop Server via a WAN.

**Local:** The Webtop Server and client communicate via a LAN.

**Exhibit 3** How the N-tier Architecture Works
Sun's Performance

Net Income  355.8  476.4  762.4  762.9  1,031.3  1,854.0  927.0  (587.0)  (3,429.0)  (388.0)  (106.0)
Today

- 3-tier model common.
- Sun’s version of 4-tier model not-common.
- N-tier model where Webserver and Application Server on separate equipment also common.
- Sun’s hardware business not strong.
  - Linux on cheap PCs most common servers
  - *Microsoft* desktops replacing Sun workstations
Today

- **Java**
  - Common in Server implementations
    - Example: Java Servlet implementing application logic in a banking application.
  - Often used to push simple applets onto client
  - Not common
    - For “big” desktop applications
    - Office Suite in Java not popular
  - *Microsoft is still in business...*
Architecture Example
Conceptualization

What is it you are trying to do?

Example Concept:

- Small HHC for flight attendants.
- HHC tells flight attendants which passengers are higher priority.
  - Who paid the highest fares
  - Who has been a more valuable customer in past
- Flight attendant discriminates based on this
  - Free drinks, meals, and pillows to valuable customers
  - Ignore less valuable customers
Example Concept:
Architecture

- How do you begin to architect a solution for a problem like this?
- Break it into modules!
Architecture

- HEADQUARTERS
  - Airline Dataserver
- HHC Server
- Wireless Link
- HHC
- Airline Intranet
When a module is composed of sub-modules, the architecture is **hierarchical**.
We are using a *layered architecture* as well.
- Allows reuse of previously built infrastructure.
Granularity tradeoff.

- How big should we make the modules
  - Many simple small ones
  - Or a few complicated big ones...

- This aspect of modularity is called *granularity*.

- Which is better?
Again, we see layering and hierarchy. Between each module we specify an interface.
Our architecture makes use of the Existing interface of the airline database, so we don’t need to redesign it!
A simple interface: from within our HHC Server Architecture

- Computation of key statistics
  - List of numbers
  - Compute Mean and Variance
    - Mean, Variance

- HHC Application
- Palm OS
- Networking Infrastructure
- Communication with HHC
- Computation of key statistics
- Communication with airline database
Interface specifications are often made precise by using **data types**.

- Example type: float
  - A number with a decimal place
  - Has a certain allowable range, and precision.
More on Data types

- Data passing an interface is often specified in terms of a limited number of standard data types.

- Data type = range of values and allowable manipulation.

- Data type does not presume a specific representation, to allow heterogeneous platforms.
  - Representation must be known when data passes a specific module interface.
Example data types

Integer

- “natural number between -32,767 and +32,768”
- Could be represented (in many ways) by 16 bits
  - since $2^n = 65,536$

Float

- “number of the form $m \times 10^n / 32768$, where $m$ is in the range -32,767 to +32,768 and $n$ is in the range -255 to +256”
- Could be represented by $16 + 8 = 24$ bits
More data types

Character
- “values assuming a-z and A-Z plus space and punctuation marks”
  - could be represented by 7 or 8 bits

Character string
- “collection of \( n \) characters, where \( n \) is customizable”
  - could be represented by \( 7 \times n \) bits
Compound data types

Programmer-defined composition of basic data types

Example:

```java
Employee {
    String name;
    String address;
    Integer year_of_birth;
    etc.
}
```
Interfaces

PARAMETERS

N numbers of Float type

INTERFACE

Computation of key statistics

Compute Mean and Variance

2 Numbers of float type that signify: Mean, Variance

RETURNS
One module should not be concerned with other module’s implementation

→ “Separation of concerns.”

One module should see the other only through its interface - implementation details hidden.

→ Abstraction
Implementation

Module A

- Computation of key statistics

Module B

- Compute Mean and Variance

Implementation 2:

\[
\begin{align*}
\text{SUM} &= \sum_{i=1}^{N} x_i \\
\text{MEAN} &= \frac{\text{SUM}}{N} \\
\text{VARIANCE} &= \frac{\sum_{i=1}^{N} (x_i - \text{MEAN})^2}{N}
\end{align*}
\]

- Though different, this implementation is ok too.

- We can choose the implementation details however we want, as long as we comply with the agreed interface.
Implementation

Module A

Computation of key statistics

Module B

Compute Mean and Variance

Implementation 1:

$X_i, i=1..N$

$\text{MEAN, VARIANCE}$

$\text{SUM} = \sum_{i=1}^{N} x_i$

$\text{MEAN} = \frac{\text{SUM}}{N}$

$\text{VARIANCE} = \sum_{i=1}^{N} (x_i - \text{MEAN})^2$

Should he use it?

- NO!!!! Why??

Either A should compute “SUM” himself, or sit down with B and redesign the interface
Encapsulation

- The designer of B might take measures to hide “SUM” from A so that A is not able to violate the agreed interface.
  - Example: B does not declare “SUM” as a global variable.

- Making a modules implementation details inaccessible to other modules is called encapsulation.
This simple interface example allows for only one action of module B.
- Action is "Compute mean and variance."

Other examples are possible.
Possible software interface

Menu of actions

Example:

*Action 1: Compute mean*
*Action 2: Compute variance*
*Action 3: Compute mode*
*Etc.*
Protocol

In addition to atomic actions, an interface may define protocols

- **Protocol** == finite *sequence* of actions required to achieve a higher level function

- One action can be shared by multiple protocols

- Multiple modules may participate in a protocol
Protocol Example

Hello: I’m the HHC of Airplane#1234

Hello: I’m the gate 32 server

These were the unruly passengers on last flight
“Passengers noted”

Tell me about the passengers of my next flight

Return Passenger Data

Tell me about the weather at my next destination.

Return Weather Data

(Might be passed As an array of a compound data type “passenger,” which in turn is composed of standard types like integer, and string)
Another Interface Example:
Automatic teller machine (ATM)

What is the interface between this machine and the customer?
Steps

Define available actions
Define, for each higher level function, a protocol
  - Single action or a finite sequence of actions
Interface building blocks

Message on screen or printed
- Menu of actions or returns from an action
- Touch selection of action

Keypad
- Input parameters to an action

Card reader
- Authentication, input parameters

Money output slot
- Returns money
Action: authentication

Parameters
Internal functionality
Returns
**Action: authentication**

**Parameters**
- Identity (card in slot)
- Institution (card in slot)
- PIN (typed on keypad)

*Internally, it contacts institution and matches against its database, institution noted for all subsequent actions (example of state)*

**Returns**
- Screen message (“Invalid PIN” or menu of available actions)
Action: specify_account

Parameters

Internal functionality

Returns
Action: specify_account

Parameters
- Account (touch screen from menu of choices)

Internally, choice noted for all subsequent actions (another example of state)

Returns
- None
Action: amount

Parameters

- Dollars_and_cents (typed on keypad)

Internally, amount noted (another example of state)

Returns

- Success or failure (state dependent, for example for a withdraw failure when dollars_and_cents exceeds balance)
Protocol: cash_withdrawal

What is the sequence of actions?
Protocol: cash\_withdrawal

- **authentication**: failure
- choose objective ➔ other objectives
- **account**: no accounts
- **amount**: balance exceeded!
More on layering

by
David G. Messerschmitt
Goals

Understand better

- how layering is used in the infrastructure
- how it contains complexity
- how it coordinates suppliers
- how it allows new capabilities to be added incrementally
Interaction of layers

Layer above is a client of the layer below

Each layer provides services to the layer above...

....by utilizing the services of the layer below and adding capability

Layer below as a server to the layer above
Layering builds capability incrementally by adding to what exists.
Three types of software

Application

• Components and frameworks:
  What is in common among applications

• Infrastructure:
  Basic services (communication, storage, concurrency, presentation, etc.)
Part of Microsoft vs. DOJ dispute

Microsoft position

DOJ position

Application

Components and frameworks

Infrastructure
Major layers

Network
Operating system
Middleware
Application frameworks and components
Applications
Data and information

Application
Deals with information

Assumes structure and interpretation

Infrastructure
Deals with data

Ignores structure and interpretation
Data and information in layers

- The infrastructure should deal with data, or at most minimal structure and interpretation.
- The application adds additional structure and interpretation.
- This yields a separation of concerns.
Package = file, message

In the simplest case, the infrastructure deals with a package of data (non-standard terminology)
- collection of bits
- specified number and ordering

The objective of the infrastructure is to store and communicate packages while maintaining data integrity

File for storage, message for communication
Data integrity

Retain the

- values
- order
- number

of bits in a package
Example 1

Bob sends a letter to Alice

Bob

Envelope

US Postal Service

Shipping Container

ABC Airlines

Alice

Envelope

UK Royal Mail

Shipping Container
Example 2

Web server

Web browser

Screen

HTML

File

Message

File system

Network

Fragmentation

Collection of packets

Assembly

Application

Operating system

Network
Example 3

HHC Server

HHC Server Application

Windows OS

Networking Infrastructure (Contains: TCP/IP, WiFi)

Passenger Information

HHC Client Application

Palm OS

Collection of Packets

Networking Infrastructure (Contains: TCP/IP, WiFi)
Example 3: Network Infrastructure Expanded

HHC Server Application

- Windows OS
  - TCP transport layer
  - WiFi Link Layer
  - WiFi Physical Layer
  - Networking Infrastructure

Passenger Information

HHC Client Application

- Palm OS
  - TCP transport layer
  - WiFi Link Layer
  - WiFi Physical Layer
  - Networking Infrastructure

- Packets
- Radio Signals

- message
Example 4

HHC Server Application → "Send me today’s flight information" → DBMS

message → Windows OS

Networking Infrastructure Layers within TCP/IP, WiFi

message → Unix OS

Networking Infrastructure Layers within: TCP/IP, WiFi
Information in the infrastructure

Sometimes it is appropriate for the infrastructure to assume structure and interpretation for data

- to add capabilities widely useful to applications
- to help applications deal with heterogeneous platforms, where representations differ

At most, data types
Data and information

Application
Deals with information

Infrastructure
Deals with data types

Assumes structure and interpretation
Assumes standard data types